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Spin-polarized current and tunnel magnetoresistance in heterogeneous single-barrier magnetic tunnel junctions

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HIGHLIGHTS

- A model of heterogeneous tunnel junction is developed.
- The model takes into account Volta potential and the difference of effective masses.
- Calculations was done for Fe/MgO/Fe-like structures.
- It is shown the influence of the structure parameters on TMR.

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ABSTRACT

Current in heterogeneous tunnel junctions is studied in the framework of the parabolic conduction-band model. The developed model of the electron tunneling takes explicitly into account the difference of effective masses between ferromagnetic and insulating layers and between conduction subbands. Calculations for Fe/MgO/Fe-like structures have shown the essential impact of effective mass differences in regions (constituents) of the structure on the tunnel magnetoresistance of the junction.

1. Introduction

Currently, layered magnetic nanostructures FM/I (ferromagnet/insulator) is one of the most exciting and rapidly developing areas of spintronics. Effects of tunneling magnetoresistance (TMR) and magnetization switching in such structures are used in magnetic field sensors, nonvolatile magnetoresistive memory (MRAM, ST-MRAM), resonant tunneling diodes, spin transistors [1,2,3]. In this report, I investigate theoretically the asymmetric (heterogeneous) one-barrier magnetic nanostructures $FM_L/I/FM_R$. They consist of two ferromagnetic metal layers separated by non-magnetic dielectric (insulating) layer. As a ferromagnetic layers material, Fe, Co, Ni and their alloys (CoFeB, FeNi) are considered. Insulating layer is usually AlO_x or MgO. Magnetization of one of the ferromagnetic layers (FM_L or FM_R) is pinned by exchange bias. Magnetization of the other layer can be changed by an external magnetic field.

Usually, one considers two situations referring to relative orientations of the ferromagnetic layer magnetizations. P-orientation (parallel) is referred to the case when magnetizations of the both ferromagnetic layers are parallel, AP-orientation (anti-parallel), when the magnetizations of the layers are directed opposite to each other. If we apply bias voltage to the external electrodes, a current flows across the structure. It is due to quantum mechanical tunneling of electrons through the barrier. Resistance of the structure depends on relative orientations of the ferromagnetic layers. The relative difference between resistances in the P and AP alignments may reach tens of percent at room temperature [4].

In early works the Julliere model [5] was used for description of the tunneling magnetoresistance in magnetic tunnel junctions (MTJ). This simple model considers TMR as a result of spin polarizations of the ferromagnetic electrodes. Slonczewski [6] further improved the Julliere model utilizing quasi-one-dimensional free electron model, however, the model could not predict negative TMR ratio at certain applied voltages that was obtained in experiment [7]. Similar approximations were made by Bratkovsky [8] (for half-metallic systems), and MacLaren [9] (comparison of

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